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USCG 680 kHz BROADCAST ANALYSIS

Prepared by

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of

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This report has been reviewed and is approved for publication.

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USCG 680 kHz BROADCAST ANALYSIS

BACKGROUND

The United States Coast Guard (USCG) has requested that ECAC analyze the electromagnetic compatibility (EMC) impact that would result from the installation of a standard broadcast station in close proximity to USCG and Naval radio facilities at Point Barrow, Alaska. The Coast Guard and Naval transmitting station is located about 300 feet from the proposed station site and the accompanying government receiver site is about 1.5 miles away.

The proposed broadcast station will transmit in the commercial AM broadcast band. Some of the characteristics of the broadcast transmitter are summarized in TABLE 1.

CONTINUED

TABLE 1

TECHNICAL DATA FOR THE PROPOSED
POINT BARROW BROADCAST TRANSMITTER

LOCATION	FREQUENCY	ANTENNA TYPE	POWER	OCCUPIED BW
71° 18.26' N 156° 45.42' W	680 kHz	top-loaded monopole (150 ft.) 1.5 dB gain	10 kW	30 kHz maximum

OBJECTIVES

The objectives of this analysis were:

(1) To determine the EMC of the proposed Point Barrow standard broadcast station with respect to the adjacent Coast Guard/Naval communications station and other communications facilities in the vicinity of the proposed site; and

(2) To determine the areas within which the radiation hazards criteria for personnel, fuel and ordnance will be exceeded.

ANALYSIS

Analysis was conducted of potential non-linear interactions and high-power susceptibility to the electronic environment surrounding the proposed transmitter. The non-linear analysis included harmonic and intermodulation response/emission calculations and the high-power susceptibility analysis determined the areas surrounding the proposed site where the field intensity produced by the transmitter will exceed the high-power susceptibility criteria of the various equipment in the environment.

The potential for co-channel and adjacent channel interference with other standard broadcast stations was not considered. It was assumed that the Federal Communications Commission (FCC) performed the necessary analysis prior to licensing the Point Barrow Broadcast station.

For radiation hazards analysis, the electromagnetic radiation intensity levels produced by the proposed transmitter were calculated in the vicinity of the antenna site. Distances within which the field strength would exceed the radiation hazards criteria for personnel, ordnance or fuel were calculated.

The Electromagnetic Environment

The electromagnetic environment surrounding the site was determined by compiling data from the ECAC environmental files. The compiled data consisted of records from files of the Interdepartmental Radio Advisory Committee, Federal Aviation Administration (FAA), Commander-In-Chief Alaska, Federal Communications Commission (FCC) and International Telecommunications Union. The resulting environment depicted the fixed-location spectrum users surrounding the site, and included Coast Guard, Navy, Air Force, FAA, non-government (FCC) and internationally (ITU) recorded users of the spectrum.

In order to reduce the size of the electromagnetic environment that would be considered in this analysis, calculations of the maximum received out-of-band interference power at a hypothetical isotropic antenna were performed at various distances from the proposed transmitter site. The calculated powers were then compared to representative receiver threshold data in order to determine the maximum distance of possible interference to a hypothetical victim receiver.

Calculations of hypothetical received power (P_R) were based on the maximum allowable out-of-band emission standards for AM standard broadcast stations as specified by the FCC. For 10 kw transmitters, this standard is -10 dBm maximum allowable emission at frequencies separated more than 75 kHz from the center frequency.[1] Assuming a 0 dBi transmitter antenna gain at out-of-band frequencies, the calculation of received power was based on the following relation:

$$P_R = P_T + G_T + G_R - L_P - OFR \qquad (1)$$

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[1] FCC Rules and Regulations, Vol. III

where P_R = Power received in dBm.

P_T = Power transmitted in dBm

G_T = Gain of transmitter antenna (assumed 0 dBi).

G_R = Gain of receiver antenna (assumed 0 dBi).

L_P = Propagation Loss (dB).

OFR = Off Frequency Rejection (dB) (0 for on-tune).

The propagation loss was calculated using smooth earth calculations at a frequency of 1.0 MHz and with assumed receiver antenna heights of 30 feet. Ground constants were assumed to be typical tundra constants (relative permittivity E_r = 5.0, conductivity σ = .0004).

The power (P_R) received by an isotropic antenna was determined for various distances from the transmitter site. A typical receiver threshold for interference was assumed to be equal to the sensitivity of the more sensitive MF or low HF receivers found in the area (-105 dBm). The distance that corresponded to a received power of -105 dBm from a transmitter source of -10 dBm, was found to be approximately 20 miles. Thus, the out-of-band receiver environment was further reduced to those receivers located within 20 miles of the transmitting antenna.

Harmonic Analysis

The harmonic interference calculations were based on a maximum allowable harmonic emission of 80 dB down from the fundamental emission. Due to the antenna mismatch attenuation of greater than 40 dB and increased propagation loss at higher harmonic frequencies, the harmonic emissions greater than the 6th order were determined to be insignificant at distances greater than approximately 1 mile. Since the data file showed no MF or HF receivers operating within 1 mile of the proposed site, the harmonic analysis was not extended beyond the 6th order. However, the antenna mismatch characteristics may fluctuate significantly with the 2nd through 6th harmonics and thus, a 0 dBi antenna gain was assumed for the harmonic calculations involving the 2nd through 6th order harmonics.

The fundamental emission spectrum was modeled using the FCC emission standards as an emission envelope approximation. This fundamental emission spectrum was subjected to N successive convolutions to represent the emission spectrum of the Nth harmonic emission. With the harmonic emission level assumed to be -10 dBm and the harmonic emission spectrum of each of the 2nd through 6th order harmonics available from the convolution calculations, the effect of each harmonic on the surrounding environment could then be determined.

For each harmonic emission, the records in the defined environment were searched for those representing receivers whose bandwidth overlap may render them susceptible to interference at the harmonic frequencies. Each case that was determined as having bandwidth overlap with the harmonic spectrum was considered a potential victim and examined further.

For each potential victim the received power at the victim (P_R) was calculated using equation (1). The propagation loss (Lp) was computed using smooth earth approximations and the tundra ground constants. The OFR characteristics of each potential victim were approximated by the convolution of an assumed receiver selectivity curve (rectangular with 3 dB point bandwidth) and the harmonic spectrum. The power received was then compared to the assumed receiver threshold level (again -105 dBm). The potential victims that may experience levels exceeding the threshold level were noted.

The analysis indicated that harmonic interference to range-tuned FAA equipment in the vicinity of the proposed station may be experienced on the frequencies shown in TABLE 2. The FAA receiving facilities are located at 71° 17' 18" N/ 156° 46' 43" W and 71° 18' 50" N/ 156° 42' 32" W, both located 1.2 miles from the proposed site.

Propagation conditions over artic ice are drastically changed as the ice thaws. As a result, shipboard receivers operating within 20 miles of the proposed site during summer months, may also be susceptible to harmonic interference.

TABLE 2

SECOND THROUGH SIXTH HARMONICS OF PROPOSED STATION (kHz)

1360	2040	2720	3400	4080

Intermodulation Interference

In order to reduce the environment to a workable size, the maximum distance at which receivers would be susceptible to intermodulation effects had to be determined. The two-signal intermodulation power (P_{im}) was determined using the following basic relationship:

$$P_{im} = mP_1 + nP_2 - K_{m,n} \qquad (2)$$

where, P_{im} = intermodulation product power (dBm)

P_1 = effective on-tune power of transmitter 1 (dBm) (received or transmitted)

P_2 = effective on-tune power of transmitter 2 (dBm) (received or transmitted)

$K_{m,n}$ = conversion loss term for the m+n order (dB)

For receiver intermodulation, typical values of $K_{m,n}$ were assumed for receivers in the environment. The values of P_1 and P_2 depend not only on the transmitted powers of both the broadcast transmitter and another participating transmitter, but depend also on OFR at the receiver and the propagation loss between the transmitters and the receiver. Calculations indicated that the receivers in the environment must be within approximately 1 mile of the proposed transmitter site in order to be susceptible to receiver generated intermodulation interference. Since the environmental data indicates that all MF and HF receiving facilities are separated more than 1 mile from the transmitter site, it was concluded that receiver generated intermodulation is highly unlikely.

For transmitter intermodulation, typical values of $K_{m,n}$ were assumed for transmitters operating within the environment. P_1 was assumed to be the power of the transmitter that generates the products and P_2 was assumed to be the power of the other participating transmitter minus the propagation loss and OFR. It was determined that, for the types of equipments found, two participating transmitters must be within approximately 1 mile of one another in order to produce intermodulation products of sufficient power levels to be detectable at any receivers in the environment. Furthermore, it was determined that only the 2nd, 3rd, 4th and 5th order products were of concern. Thus, the environment was reduced to a representation of all transmitters operating within 1 mile of the proposed site.

In order to determine the potential for intermodulation interference, data on all the transmitting frequencies used within 1 mile of the proposed site were assembled. Two signal 2nd, 3rd, 4th and 5th order intermodulation combinations of the broadcast transmitter frequency

(680 kHz) with any transmitter frequencies operating within 1 mile were considered. The resulting list of intermodulation product frequencies was compared to a list of receiver frequencies operating within a 20 mile radius. In each case that indicated a potential for interference to the surrounding environment, equation 2 was implemented to provide an approximation to the emitted intermodulation power (P_{im}). Calculations of received interference power (P_R, using equation 1) were performed for potential victim receivers and compared with the assumed -105 dBm sensitivity threshold.

Calculations indicate that transmitter intermodulation products produced within the USCG/Naval transmitter antenna farm (cosited with the proposed antenna) may result in detectable interference levels when certain frequency combinations are operating simultaneously. TABLE 3 identifies possible transmitter intermodulation combinations and potential victim receivers.

High-Power Interference Analysis

The field intensity levels that will be produced by the top-loaded monopole were calculated by an antenna modeling program. This program models the entire antenna structure, including ground screen, as a series of segmented current elements conforming to the antenna geometry. The net contribution of these current elements to field intensity is computed for various distances from the antenna structure. All calculations were performed for a height of 6 ft. above the surface of the earth.

TABLE 3

LIST OF POTENTIAL TRANSMITTER INTERMODULATION COMBINATIONS INVOLVING THE PROPOSED STATION OPERATING AT 680 kHz

Environment Transmitter	Order of Product	Victim Receiver
71° 18' xx" N 156° 47' xx" W Freq. = 2183.4	2nd	71° 17' 21" N 156° 46' 05" W Freq. = 2861.0 (FAA receiver)
71° 18' xx" N 156° 47' xx" W. Freq. = 2183.4	2nd	17° 17' 21" N 156° 46' 05" W Freq. = 2862.5
71° 18' xx" N 156° 47' xx" W Freq. = 2911.5	3rd	71° 17' xx" N 156° 46' xx" W Freq. = 5148.5
71° 18' xx" N 156° 47' xx" W Freq. = 2911.5	3rd	71° 17' xx" N 156° 46' xx" W Freq. = 5151.5

xx - seconds portion of location not reported.

The analysis of field intensity levels produced by the broadcast transmitter indicates that the standard for high-power susceptibility levels for VHF/UHF non-sheltered equipment[2] (10 volts/meter) will be exceeded within 500 meters of the transmitting site. Thus, VHF or UHF equipment operating within 500 meters may experience undesirable high power effects if not sheltered in accordance with the Mil Std.

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[2] Mil Std. 461-A

The high-power effects criterion for sheltered equipment (50 V/m) is not exceeded beyond 45 meters from the antenna.

Radiation Hazards Analysis

Near-field and far-field calculations (as applicable) were performed using an antenna modeling program to determine field intensity levels that will be produced by the proposed top-loaded monopole. The results of the calculations are shown in TABLE 4. The "distance" column in the table is that distance beyond which the calculated field intensity or power density level does not exceed the cited hazard criterion. All field intensity levels were calculated at approximately six feet above ground. The calculations assume full output power and 100% modulation of the broadcast carrier.

It should be noted that the field intensity calculations show the fields produced only by the proposed station. The cumulative effects of simultaneous operation of adjacent high-power transmitters could not be considered due to the manpower limitations of this analysis. Resulting fields could be additive, but the resulting increased fields would exist for only very short time intervals.

RESULTS

As a result of the EMC Analysis, it has been determined that:

1. Harmonic interference may be detectable in range tuned FAA receivers located at 71^{o} 17' 18" N/ 156^{o} 46' 43" W and 71^{o} 18' 50" N/ 156^{o} 42' 32" W, if they are tuned to 680, 1360, 2040, 2720, 3400 or 4080 kHz.

TABLE 4

RADIATION HAZARDS SUMMARY FOR POINT BARROW BROADCAST STATION

Type of Hazard	Hazard Criterion	Hazard Distance #	Document of Reference for Criteria
Biological, Personnel (continuous exposure)	10 mW/cm^2	25 meters	NAVSO P-2455 Safety Precautions for Shore United States Navy
Hero Susceptible Ordnance	160 V/meter	35 meters	NAVORD OP3565/ NAVAIR 16-1-529 Technical Manual, RF Hazards to Ordnance Personnel and Fuel
Hero Unsafe Ordnance	1.5 V/meter	1400 meters	same as above
Nuclear Weapons (Assembled)	200 V/meter	25 meters	AFSCM 122-1 Nuclear Systems Safety Design Manual
Nuclear Weapons (During assembly/ disassembly)	3 V/meter	850 meters	same as above
Stored Fuel	5 W/cm^2	0 (will not be exceeded)	T.O. 31Z-10-4 Electromagnetic Radiation Hazards
Fuel in Transfer	90 V/meter	35 meters	AD 900 912L NESTEF Development of Fuel Hazards Criteria in RF Fields

#Distance beyond which calculated field is less than hazard criterion.

2. Shipboard and other mobile receivers operating within 20 miles of the proposed site during summer months may experience harmonic interference on the tuned frequencies listed above.

3. Receiver generated intermodulation interference is highly unlikely due to the distance separation between transmitting and receiving facilities.

4. Transmitter intermodulation products may result in detectable interference when the frequency combinations listed in TABLE 3 are operated simultaneously.

5. The Mil Std. 461-A maximum tolerable field intensity criterion for non-sheltered VHF or UHF equipment will be exceeded within 500 meters of the proposed transmitter site. Thus, the VHF and UHF facilities located within the USCG/Naval transmitting complex may be susceptible to high power effects. The VHF/UHF facilities should be evaluated, however, to determine if the standard for sheltered equipment (50 V/meter) is applicable to the equipment because the value of fifty V/meter is not exceeded beyond 45 meters from the antenna.

6. The results of the radiation hazards analysis are summarized in TABLE 4 and their impact should be considered prior to construction of the broadcast station. Although an accepted criterion for cardiac pacemaker susceptibility has not been established, the field intensities produced by the transmitter should be considered a potential hazard to pacemaker wearers in the near-field region of the antenna.

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